Chapter 5
Penstock Shutoff Valves at the Powerhouse

5-1. General

Butterfly and spherical valves are typically used at Corps of Engineers projects when shutoff capability is required at the powerhouse end of the penstock. Mechanical design responsibilities for these valves include the determination of need, selection of type and size, selection of auxiliary equipment, coordination of location and space requirements, preparation of contract drawings and specifications, review of contractor submittals, and preparation of instruction manuals.

5-2. Valve Requirement

A shutoff valve may be required at the powerhouse end of penstocks for either turbine or pump-turbine units. The purpose of this valve is to provide emergency shutoff in case of flooding-type failure or loss of speed control, reduction of leakage through wicket gates, and for maintenance of the turbine. However, shutoff provisions are usually required at the intake of each penstock. As a result, a shutoff valve at the unit may not be required. Several factors should be considered when deciding the need for a shutoff valve at the unit. The factors include but are not limited to the following:

a. Type of shutoff at the penstock intake. A quick closing shutoff at the penstock intake, operable under emergency conditions, may be an alternative to a shutoff at the powerhouse. Where maintenance and emergency shutdown can be satisfied with the intake shutoff, the requirement for powerhouse valves can seldom be justified.

b. Length of penstock. A long section of penstock downstream of the shutoff will increase the time required to shut the unit down during an emergency closure, increase the time required to unwater the unit, and increase leakage losses. Maintenance and emergency shutdown requirements will usually justify a powerhouse shutoff when the penstock is several hundred feet long.

c. Head. A shutoff valve near the unit will reduce the effective head on the unit, which in turn will reduce the leakage.

d. Multiple units per penstock. Operational and maintenance flexibility will normally require a separate shutoff valve for each unit. Generally, maintenance requirements alone will justify powerhouse shutoff valves for multiple unit penstocks.

e. Type of wicket gate seal. A tight seal reduces leakage losses. However, deterioration of the seal with time should be considered when determining the effects of leakage.

Evaluation of the factors should consider their effects on maintenance, emergency operations, and costs. The factors considered and basis of determination should be included in the mechanical design memorandum.

5-3. Valve Selection

Butterfly and spherical valves are generally available as a catalog item for heads up to 183 m (600 ft) and in sizes up to 2.4 m (8 ft). Valves for conditions exceeding these limits are typically designed for the specific application. Factors to be considered include initial cost, maintenance, head loss through valve, and requirements for transition sections.

a. Spherical valves.

(1) General. Spherical valves consist of a valve body, valve rotor, bearings, and operator. In the open position, the rotor has a full diameter water passage axially aligned with the penstock. Head loss through the valve in the full open position is approximately the same as an equal length of penstock. When rotated 90 deg (the closed position), the valve presents a solid surface, closing the water passage. Movable seal rings permit tight shutoff. Wear of the sealing surfaces is minimized because the wear rings are not in contact with the mating surfaces until after valve rotation is complete. Fabrication and machining costs are relatively high when compared with butterfly valves.

(2) Detail requirements are as follows.

(a) Design conditions. Valves should be designed for maximum penstock head including water hammer. Because of the significance of a water hammer, studies should be conducted and documented in the design process. Since the valve may be used to test the penstock and/or spiral case, and during spiral case grouting, the design should also be adequate for these heads as applicable. The installation may require the valve to withstand heads from either direction when closed. If the valve is to be used for emergency closure, the operator should be capable of closing the valve in 2-5 min as practicable for the size.

(b) Valve body. The valve body should be made in halves of fabricated or cast steel, properly annealed, and adequately designed to resist the hydraulic forces acting directly on the body and those resulting from the thrust for any position of the valve rotor. Integrally cast or forged (if fabricated) steel flanges, suitably machined, should be provided for bolting the body pieces together and circumferential flanges for bolting to the pipe extensions.

(c) Rotor. The valve rotor should be made in one piece of annealed cast or fabricated steel and should adequately resist the bending and shearing load resulting from the hydraulic and operating forces.

(d) Seals. Retractable seal rings should be provided to permit separation of the sealing surfaces during rotation of the rotor. Sealing surfaces should be corrosion resistant and of different composition and hardness to minimize galling. One seal of 300 series stainless and one of 400 series stainless will perform satisfactorily in most waters. However, the source water should be checked for unusual corrosiveness. Then the materials should be specified accordingly. Both sealing surfaces should be removable for replacement. The retractable seal ring should normally be oil-hydraulically operated. Both upstream and downstream seals may be justified to allow more flexibility in scheduling of seal replacement.

(e) Trunnion bearings. Trunnion bearing with renewable self-lubricating bronze sleeves and bronze thrust washers should be provided. Bearing housings should be integral to the body casting. A means of adjusting and centering the rotor should be provided. Pressure relief for leakage water through the gland should be verified.

(f) Bypass. A bypass valve permitting equalized pressure on both sides of the spherical valve before opening should be provided. The bypass is normally motor operated for automatic control.

(g) Valve operator. A double-acting hydraulic cylinder operator should be provided for opening and closing the valve. The operator should be capable of closing the valve at maximum pool head and maximum discharge. Opening capability should be at balanced head conditions. The operator should also be suitable for continuous pressurization to hold the rotor in either the fully closed or open position. All valve and operator components subject to loading from operator action should be designed for the maximum hydraulic cylinder forces.

(h) Operator control. The type of control should be appropriate for normal unit operation and emergency shutdown requirements. Pumps are normally on pressure switch control and are protected with relief or unloading valves. Cylinder action is normally controlled with motor-operated tight sealing four-way valves and pressure-compensated flow control valves set to obtain the required opening and closing times. Spool-type control valves are not suitable for extended pressurizing periods in one direction. Impurities tend to filter out in the spool clearances causing sticking and failure to operate. Gauges, isolating valves, filters, alarms, control panels, and limit switches should be provided as applicable.

(i) Pipe extensions. Pipe extensions for connecting the valve to the penstock and spiral case extension are generally procured with the valve. The extensions should be designed on the same basis as the penstock. One end of each extension should be provided with a flange to connect to the valve flange. The other end of each extension should be prepared for a welded and or sleeve-type connection, as required. When required, the sleeve couplings are normally procured with the extensions.

(3) Safety provisions.

(a) A lockable, mechanical latch should be provided for securing the valve in the closed position. The latch should be capable of withstanding any opening force obtainable from the hydraulic operator to protect workmen from accidental opening of the valve.

(b) A mechanical hydraulic hand pump and manually operable control valves should be provided for manual operation of the valve in either direction.

(c) The valve operating cylinder should be cushioned to prevent damage due to the valve slamming in the event oil pressure is lost.

(d) Additional flow control valves should be provided in the hydraulic circuit at the cylinders. These valves should limit the flow to 125 percent of normal closure flow if line pressure is lost.

(e) Hydraulic pumping capacity should be provided with two pumps in a lead-lag control arrangement, either of which is capable of performing a normal opening or emergency closing.

(f) Accumulators should be provided in the hydraulic system with capacity sufficient to fully close or open all spherical valves on the system with both pumps inoperative after the low system pressure alarm has been activated.

(g) All parts and components subject to loading from operation of the hydraulic operator should be designed for maximum stress of 75 percent of yield point with a maximum attainable pressure in the cylinder. Maximum attainable pressure should be assumed as either pump shutoff pressure or maximum setting of the relief valve sized for maximum pump delivery.

(h) Valve bodies and rotors should be hydrostatically tested at 150 percent of design head in both directions and with rotors open and closed.

(4) Design. Design of spherical valves and operators should be specified as a contractor responsibility. However, the valves are a critical item in obtaining and maintaining satisfactory unit operation. Therefore, the specifications should require equipment of a design proven in service. Standard catalog equipment is preferred when available. Where a size and head rating not previously in use is required, the specifications should require the bidder to have experience in designing and manufacturing similar valves of the approximate size and head rating.

b. Butterfly valves.

(1) General. Butterfly valves consist of a valve body, valve disc, bearings, and operator. Head loss through a butterfly valve is higher than for a spherical valve. Losses are higher for lenticular-type disks versus the open truss-type disc. Head loss may justify an oversize valve with suitable transition sections. Some leakage is characteristic of the metal-seated butterfly valves.

(2) Detail requirements.

(a) Design conditions (see paragraph 5-3*a*(2)(a)).

(b) Valve body. The valve body should be of either cast or fabricated construction and include connecting flanges. Design and fabrication should be in accordance with Section VIII of the ASME "Boiler and Pressure Vessel Code."

(c) Disc. The valve disc should be of cast or fabricated construction and either lenticular or open truss design. Design stresses should not exceed 50 percent of yield point or 25 percent of ultimate at design head. Fabricated designs should be stress relieved before machining. Disc design should provide for wedge sealing action with the disc at less than 90 deg to valve axis, and the disc should have positive overtravel limits. The limit may be provided by mechanical stops or by bottoming of operator piston.

(d) Seals. Valve body and disc seals should be of corrosion resistant steel of different composition and hardness to minimize galling. Both seals should be replaceable without dismantling the valve, and the body seal should be adjustable from outside the valve. Suitability of the seal composition to resist corrosion in the penstock water should be verified by prior operating experience or chemical analysis. Seal design should not be compromised to allow a manufacturer's standard design.

(e) Valve shaft. The valve shaft for lenticular discs should be one piece. Shafts for open truss-type discs may be bolted on. Corrosion resistant sleeves should be provided at the packing boxes if noncorrosion resistance shafts are used.

(f) Bearings. Shaft bearings should be sleeve type, self-lubricated and should include adjustable thrust surfaces for centering the disc.

(g) Bypass (see paragraph 5-3*a*(2)(f)).

(h) Valve operator (see paragraph 5-3*a*(2)(g)).

(i) Operator control (see paragraph 5-3*a*(2)(h)).

(j) Pipe extensions. Pipe extension provisions for butterfly valves are generally as described in paragraph 5-3*a*(2)(i) for spherical valves. In some cases, it may be hydraulically justified to design the downstream extension as a transition section to minimize the effect of the velocity change at the valve. The downstream end of the transition section should be as required to permit the welded or sleeve-type connection to the spiral case extension.

(3) Safety provisions (see paragraph 5-3*a*(3)).

(4) Design. The design of butterfly valves and operators should be specified as a contractor responsibility. However, the valves are a critical item in obtaining and maintaining satisfactory unit operation. Therefore, the specifications should require equipment of a design proven in service. Standard catalog equipment is preferred when available. Where a size and head rating not previously in use is required, the specifications should require the bidder to have experience in designing and manufacturing similar valves of the approximate size and head rating.